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NOISE SUSCEPTIBILITY: A COMPARISON OF TWO NAVAL AVIATOR POPULATIONS

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

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SUMMARY PAGE

THE PROBLEM

Laboratory research and practical field experience have suggested that not all individuals are equally susceptible to the damaging auditory effects of high intensity noise exposure. Predictive statements regarding this differential susceptibility to noise-induced hearing loss would be of obvious value in military and industrial settings. Identification of the critical factors underlying the susceptibility is necessary for the development of noise susceptibility risk profiles.

FINDINGS

Fifty-six naval aviators, categorized as having either incurred a hearing loss (noise susceptible) or having retained normal hearing (noise resistant) after thousands of flight hours, were compared along several auditory and non-auditory dimensions. The following variables were statistically significant in their differential occurrence: Scores on the Minimal Auditory Intensity Differential test; iris pigmentation; blood type; systolic blood pressure (sitting); calcium, albumin, and LDH blood serum levels; and present tobacco usage. In addition, the noise-susceptible subject group tended ($p < .10$) to exhibit elevated cholesterol and triglyceride levels and higher contralateral acoustic reflexes, and contained fewer individuals who had never smoked.

RECOMMENDATIONS

It is recommended that those variables that were statistically significant in differentiating the two subject groups be routinely gathered in a high noise exposure population whose hearing threshold levels can be monitored over a period of years. It is further recommended that a loudness discrimination measure, such as the Minimal Auditory Intensity Differential (MAID) test, be examined in greater detail to ascertain its potential usefulness in detecting imminent hearing loss.

INTRODUCTION

A recurrent finding of research on the deleterious effects of high-intensity noise exposure is that not all individuals are equally susceptible to noise damage (1,2,3). The degree of this difference in susceptibility is frequently such that one person having a history of noise exposure will suffer a clinically significant hearing loss while another individual (with an apparently identical noise exposure history) will exhibit no hearing decrement whatsoever. Predictive statements regarding individual susceptibility to noise effects would be of obvious value in military and industrial environments, and numerous attempts at the development of a testing regimen for assessing noise susceptibility have been made over the years.

Perhaps the most popular approach in the investigation of this problem has been based on the assumption that those ears most susceptible to reversible noise-induced hearing losses (i.e., temporary threshold shifts (TTS)) would also be those most likely to be sensitive to irreversible effects (i.e., permanent threshold shifts (PTS)). While this is an intuitively appealing assumption, nearly 50 years of research have failed to develop a general TTS paradigm that possesses predictive validity for a wide range of hazardous auditory stimuli. What the TTS research has provided, though, is further confirmation of the signficant inter-individual variability of auditory fatigue effects and a greater appreciation of the complexity of the whole susceptibility question.

In an effort to develop a more fruitful approach to the question, investigators have adopted a multivariate research approach and have also begun to include non-auditory indices of noise susceptibility in their paradigms. For example, regarding non-auditory variables, research has been conducted into the relationship between iris pigmentation and noise-induced hearing loss (e.g., 4,5,6,7,8), differential rates of noise damage as a function of sex and race (9), cardiovascular function (e.g., 10), smoking behavior (7,8,11), and so on. Auditory correlates of noise susceptibility that have received attention in recent decades have included threshold octave masking (12,13), aural overload (14), the acoustic reflex (15), and loudness discrimination (16), to name a few. (See Humes (17) for a comprehensive review.)

A hallmark of virtually all studies that have taken place in field settings has been an investigative emphasis on those individuals who have been proven to possess ears susceptible to noise damage. This is certainly an understandable approach, but it may be of limited utility in arriving at statements concerning the susceptibility of ears in the early stages of exposure to hazardous noise. That is, the information gathered from what has now become a pathological auditory system may bear questionable relevance (particularly auditory relevance) to yet-to-be-exposed/damaged systems. Perhaps a more useful approach would involve greater attention to those persons who have successfully resisted the negative effects of hazardous noise exposure. Their auditory and non-auditory profiles might provide a more valid comparison with those individuals just entering the hazardous noise environment.

The purpose of the present study was to gather information on auditory and non-auditory variables (which have been reported to be related to

hearing loss) from two disparate populations--a group proven to be especially noise resistant and a population showing a more normative response to years of exposure to hazardous noise. It was hoped that this emphasis on the noise-resistant ear would provide additional information on the question of noise susceptibility.

METHOD

SUBJECTS.

Naval aviators served as our primary subject pool and, as mentioned earlier, two types of aviators were of principal interest:

Noise-Susceptible Group (Group S). This group consisted of 37 individuals who had been exposed to aircraft noise and who exhibited clinically significant hearing losses (i.e., hearing threshold levels (HTLs) greater than 40 dB at 4000, 6000, or 8000 Hz) in at least one ear.

Noise-Resistant Group (Group R). This group consisted of 19 individuals who were similarly exposed to aircraft noise but who maintained clinically normal hearing (i.e., HTLs of 25 dB or less) in both ears at 125 Hz through 8000 Hz. (We found the incidence of this group in the aviator population to be approximately 5 percent.)

To be included in one of the two populations, prospective subjects must have had a minimum of 2000 verifiable flight hours, no unusual exposures to hazardous noise outside the aviation environment, no clear hereditary predisposition to audiological problems, and no medical history of hearing pathology. In addition, the two groups were equated along as many additional potentially important dimensions as possible (e.g., age, types of aircraft flown, self-reported use of hearing protection, etc.). The preceding list of relatively stringent criteria necessitated the screening of several hundred potential subjects and resulted in population sizes that were self-limiting.

INSTRUMENTS.

Three classes of information were gathered from the two groups of aviators.

1. **Personal interview.** This was largely self-report information covering personal and family otological history, avocational and nonmilitary noise exposure, affective response to noise, subjective appraisal of hearing and of alcohol and tobacco usage, approximate number of flight hours per type of aircraft, hearing protection usage, and miscellaneous demographic items.

2. **Biomedical assessment.** This class was composed of laboratory-derived measures of blood chemistry (28 variables), cardiovascular condition (blood pressure, pulse rate), and pulmonary functioning (vital capacities, volumes, and flow rates). Blood pressures were obtained in sitting and standing positions using a Bauman sphygmomanometer, and pulmonary values were gathered on an Airco/Ohio 842 spirometer. Estimates of iris and skin pigmentation were also gathered by two judges at this time.

3. **Audiological/Psychoacoustical Assessment.** Pure-tone, air conduction thresholds were obtained using a Tracor RA-115A audiometer. Tympanograms and ipsilateral and contralateral acoustic reflex measures were obtained with an American Electromedics impedance audiometer (Model 83). An index of intensity discrimination at 2000 Hz and 4000 Hz, the Minimal Auditory Intensity Differential (MAID) test (18), was also obtained using a Tracor RA-207 MAID audiometer. Pinna projection was measured on some members of each population as well.

RESULTS

Figure 1 presents the mean hearing threshold levels of the two subject populations, and Table 1 contains their mean ages, flight hours, and hearing protector usage. These data were of primary use in the description and equation of the populations.

TABLE I

Mean age, flight hours, and hearing protection usage for the two aviator populations.

	AGE (YRS)	FLIGHT HRS	HEARING PROTECTION*	
			'Yes'	'No'
GROUP S	57.8	6833	36	64
GROUP R	56.5	5307	37	63

*Self-report; Percent responding

Table 2 contains measures that failed to occur differentially in the two groups (Student's t-test: $p > .10$).

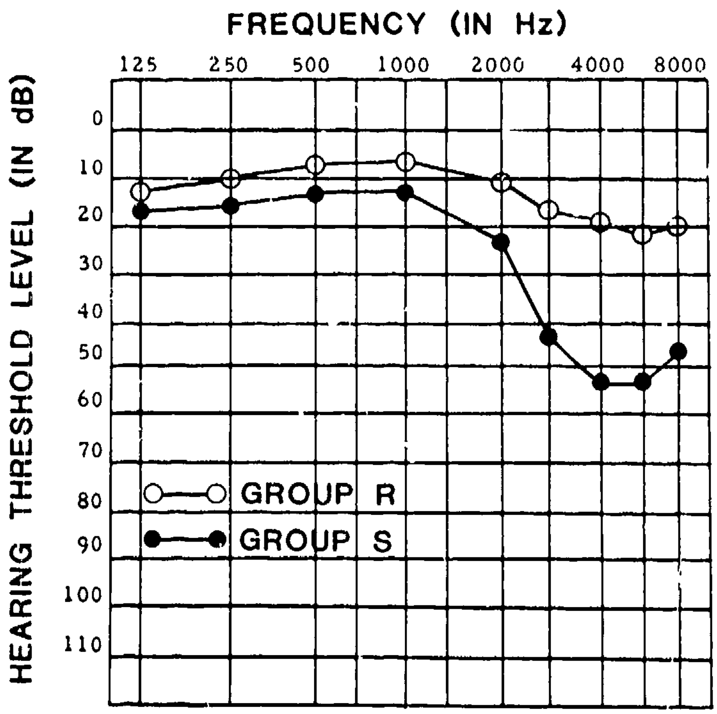

Figure 1

Audiograms of the two groups of aviators (Group R = noise resistant; Group S = noise susceptible)

TABLE II

Selected measures that failed to occur differentially in the two aviator populations.

PERSONAL (Self report)

Alcohol usage	Number of flight hours
Personal otological history	Types of aircraft flown
Family otological history	Hearing protection usage
Affective response to noise	Age

BIOMEDICAL ASSESSMENT

Blood Chemistry

Sodium, serum	Blood urea nitrogen	Glucose
Potassium, serum	Uric acid	Albumin
Chloride, serum	Protein, total	Bilirubin, total
Carbon dioxide	Phosphorus	Globulin
Carbon monoxide	CPK, total	Creatinine
Alkaline phosphatase	SGOT	

Cardiovascular

Pulse rate

Blood pressure--systolic; standing

Blood pressure--diastolic; sitting and standing

Pulmonary

Forced vital capacity

Forced expiratory volume (at 1 and 3 seconds)

Maximal expiratory flow rate

Maximal mid-expiratory flow rate

Audiological/psychoacoustical

Pinna projection	Tympanogram
Ipsilateral acoustic reflex (2000 Hz)	

Table 3 is a listing of variables that approached but did not attain traditional levels of statistical significance (Student's t-test: $p < .10$).

TABLE III

Measures that approached ($p < .10$) but did not attain traditional levels of statistical significance.

Cholesterol
Triglycerides
"Never Smoked Tobacco"
Contralateral Acoustic Reflex (at 2000 Hz)

A number of measures did occur differentially in the two groups (Student's t-test or Chi-square: $p < .05$). These are graphically represented in Figures 2 through 10. In addition to the preceding analyses, the data were submitted to a step-wise multiple regression analysis. This analysis resulted in an R-squared of .64 when the two groups were treated as dichotomous outcome variables.

DISCUSSION

Only three of the administered auditory measures occurred differentially in the two groups of aviators, and only one is of potential significance in the present research effort. The finding that abnormal MAID scores (a test of intensity discrimination and an indirect measure of loudness recruitment) occurred in Group S at 2000 Hz, a frequency at which its members were audiometrically "normal," is of some interest. A possible implication of this finding is that, since pure-tone hearing loss tends to spread downward in frequency, the occurrence of abnormal MAID scores at a frequency where pure-tone sensitivity is still within the bounds of normality implies that responses to the MAID test may presage imminent pure-tone hearing loss. This could be of significant value in hearing conservation monitoring procedures. To unequivocally answer the question, however, additional research is required and, ideally, a longitudinal study of a high noise environment population should be conducted.

Significant MAID score differences at 4000 Hz are not surprising. It has been shown that individuals with pure-tone hearing losses at a particular frequency routinely produce aberrant scores on intensity discrimination measures at that frequency (18).

Finally, the trend toward statistical significance of the contralateral acoustic reflex measured at 2000 Hz is also probably of minimal

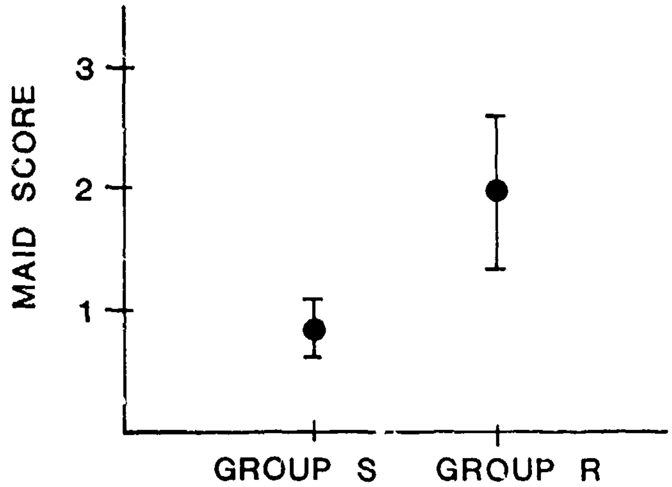

Figure 2

MAID scores at 4000 Hz (worse ear) ($t = 6.75$; $p < .001$)

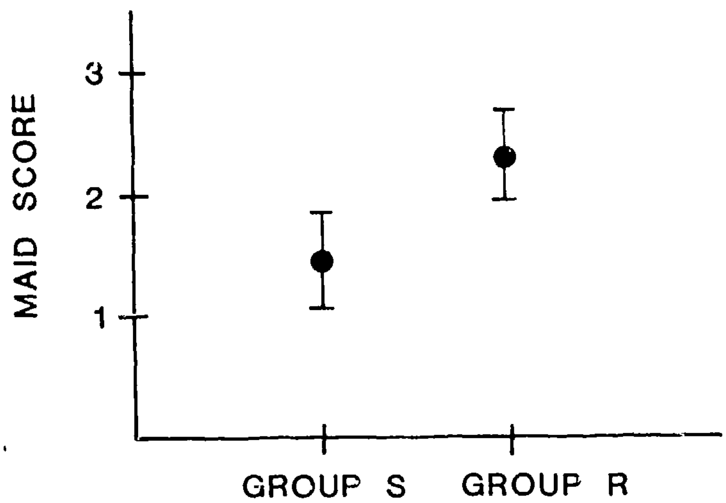

Figure 3

MAID scores at 2000 Hz (worse ear) ($t = 2.7$; $p < .01$)

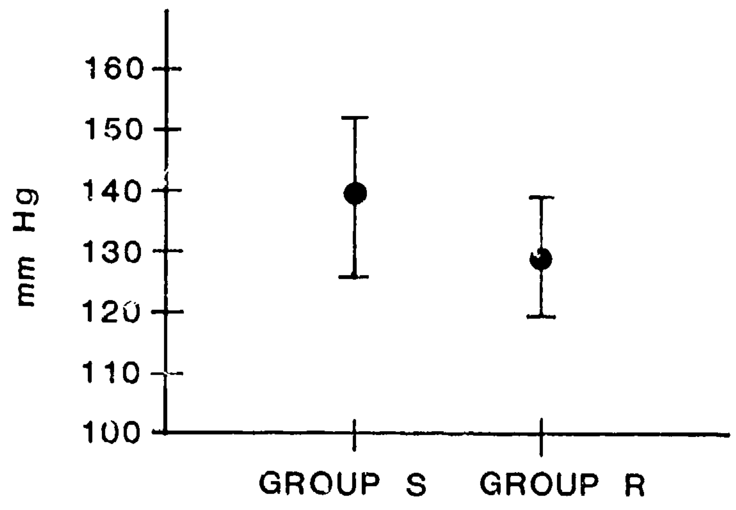

Figure 4

Systolic blood pressure (sitting) ($t = 1.67$; $p < .05$)

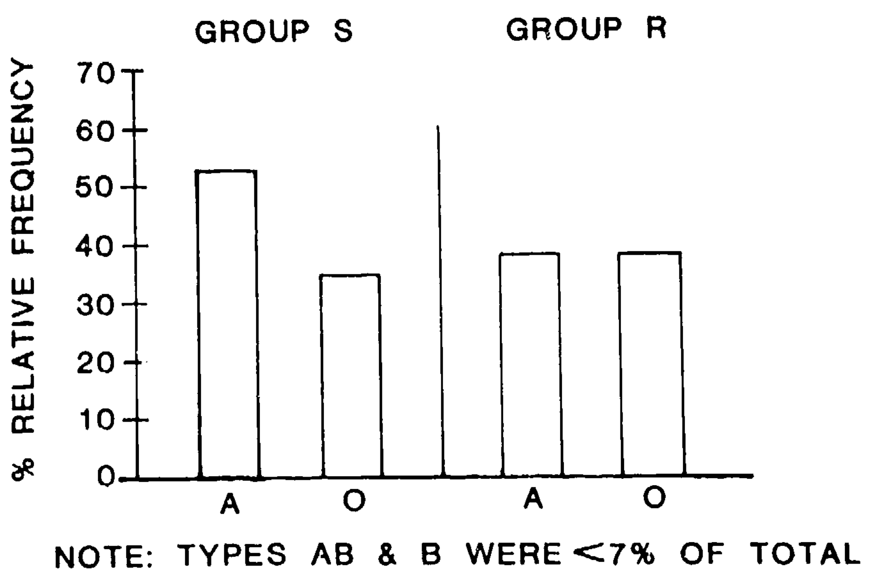

Figure 5

Blood type (Chi-square = 7.64; $p < .05$; df = 3)

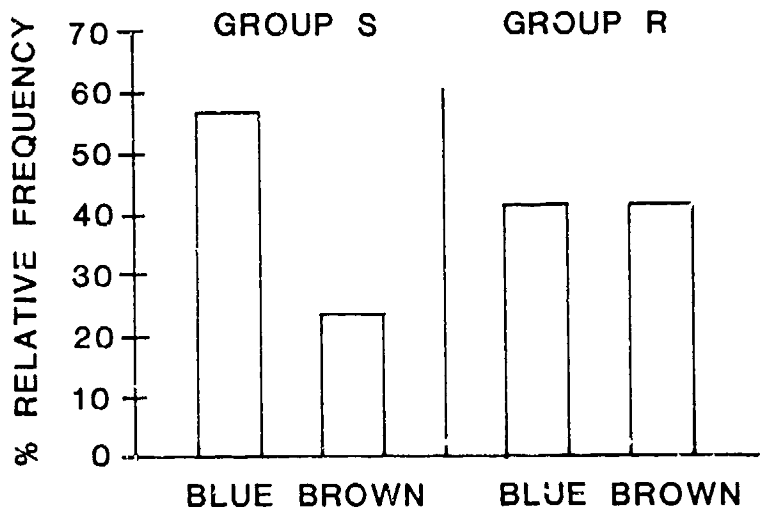

Figure 6

Eye color (Chi-square = 14.29; p <.0025; df = 3)

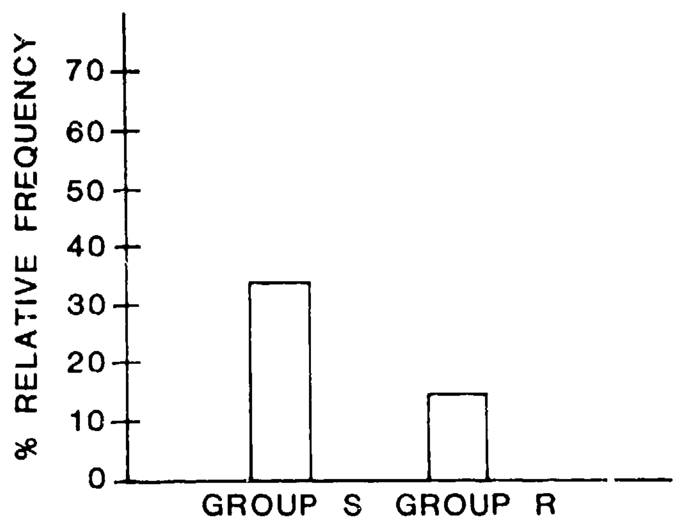

Figure 7

Present smokers (Chi-square = 8.33; p <.005; df = 1)

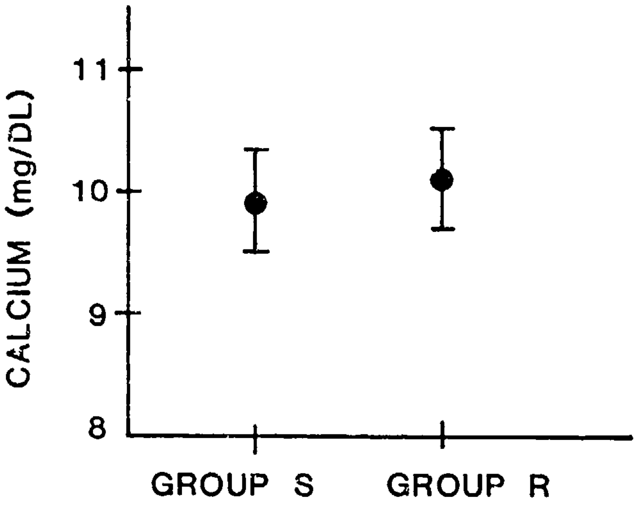

Figure 8

Blood calcium levels ($t = 1.7$; $p < .05$)

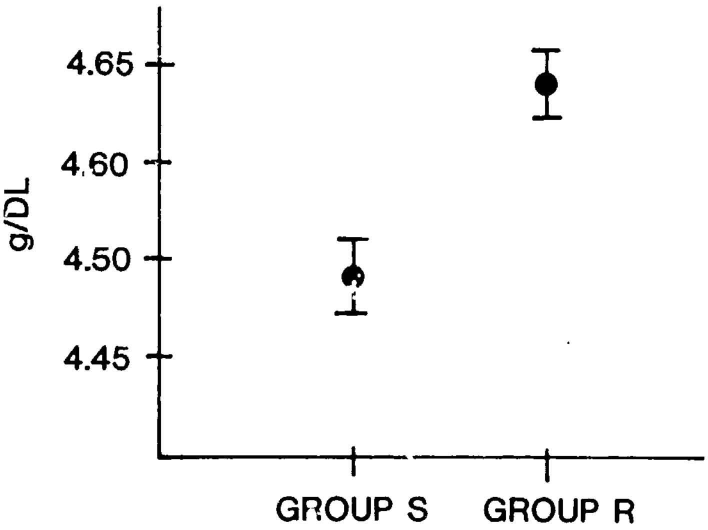

Figure 9

Blood albumin levels ($t = 1.75$; $p < .05$)

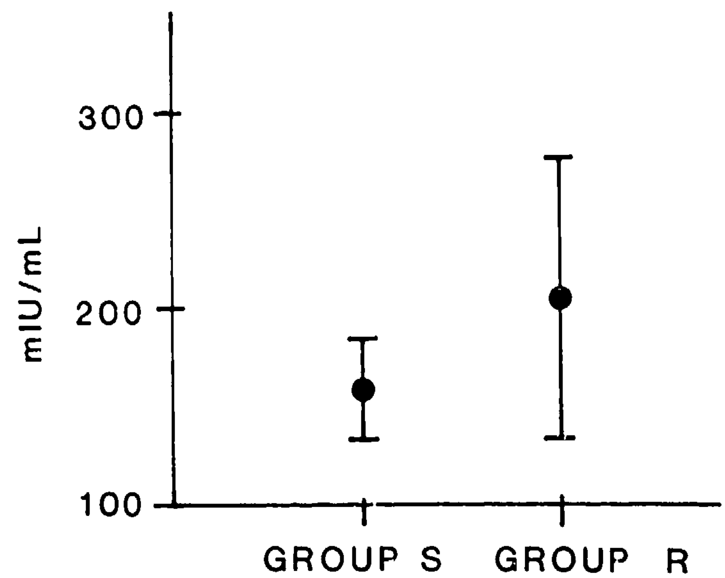

Figure 10

LDH levels ($t = 1.79$; $p < .05$)

significance. The actual difference in thresholds between the two groups was less than 3 dB (95 dB vice 92 dB), certainly too small a difference to exert a significant effect.

The non-auditory variables addressed in this study (and which tended to discriminate between the two groups) can be grossly classified into two types--those primarily of an hereditary nature and those dealing with general states of health. The first type, over which the subject has minimal control, is represented by such variables as eye color and blood type. Eye color as a significant correlate of the hearing threshold levels of individuals who have been exposed to high levels of noise has been identified by this laboratory in the past (7,8) and by other investigators (5,6,19), as noted earlier. The exact processes underlying this relationship have not been identified, but it has been posited that melanin serves an angio-protective function and that the amount of melanin present in the stria vascularis of the inner ear is reflected by the amount of melanin in the iris of the eye (19). Whatever the mechanism of operation, eye color continues to show a weak, but persistent, correlation with auditory shift responsivities in the current study. The exact significance of the finding that aviators with type A blood were significantly over-represented in Group S is unknown at this time. To the best of our knowledge, blood type has never before been included in a battery designed to assess susceptibility to hazardous noise effects. If this finding is replicated in future research, additional investigations should be conducted to determine whether biochemical or allied hereditary factors are of principal importance.

The second general classification of non-auditory measures, that dealing with the assessment of current health, supports earlier findings indicating that measures of health can be correlated with susceptibility to auditory fatigue effects and hearing loss (e.g., 20,21,22). Cardiovascular fitness and its relationship to hearing threshold levels has been specifically addressed by Rosen and his colleagues (10,22) as well as by Willson, et al. (21) and Cunningham and Goetzinger (23). The present investigators also found that the sitting systolic blood pressures of Group S subjects were significantly higher than those of Group R subjects and that the levels of cholesterol and triglycerides showed a trend toward elevation in Group S, whereas albumin and LDH were significantly higher in Group R. Furthermore, members of Group R also revealed significantly higher levels of calcium in their blood, the first time this variable has been noted by the present investigators. Reduced levels of calcium in the perilymph of the cochlea have been shown to result in a reversible depression of the action potential and a slight decrease of cochlear microphonics in the guinea pig (24), but whether this is the case in the human model is unknown.

Cigarette smoking also has been correlated with the incidence of hearing loss among noise exposed persons (8,11). In the current study, significantly more Group S subjects were currently smokers, although the two groups did not differ in the amount of tobacco consumed or the length of time the smoking habit had been established. Group R did have more aviators who had never smoked, but this difference only approached statistical significance. Related measures of pulmonary function, interestingly, did not differ in the two groups.

It should be realized that other indices of fitness such as pulse rate, pulmonary function, etc., failed to occur differently in the two groups. Also, the state of health of the subjects at the time of exposure to hazardous noise was not addressed. As a result, a generalized statement regarding measures of fitness and hearing threshold levels cannot be made at this time.

CONCLUSIONS AND RECOMMENDATIONS

The present study attempted to address the question of individual susceptibility to noise-induced hearing loss by examining all reportedly relevant variables in two populations of aviators. Although no classic profile of the noise-susceptible or noise-resistant individual definitively emerged, results suggested that at least one measurement device (MAID test) may serve as an "early warning" of imminent noise-induced damage. Further research, however, is required to test this possibility.

To answer more definitively the question of noise susceptibility, it is recommended that those variables identified in this study as being potentially important be routinely gathered in a high noise exposure population whose hearing threshold levels can be monitored over a period of years.

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The identification of characteristics of noise-susceptible or noise-resistant individuals is necessary for the development of noise-susceptibility risk profiles. Fifty-six naval aviators, categorized as having either incurred a hearing loss (i.e., hearing threshold levels greater than 40 dB at 4000-8000Hz) or retained normal hearing (i.e., hearing threshold levels less than or equal to 25 dB at 125-8000 Hz) after thousands of flight hours were compared along several auditory and non-auditory dimensions.

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The following variables occurred differentially in the two groups: Minimal Auditory Intensity Differential (MAID) scores at 2000 Hz ($p < .01$) and 4000 Hz ($p < .001$); iris pigmentation (blue eyes were over-represented in the noise-susceptible group; $p < .05$); blood type (type A occurred more often in the noise-susceptible population; $p < .05$); systolic blood pressure (sitting; noise-susceptible group was higher; $p < .05$); calcium, albumin, and LDH levels (higher in the noise-resistant group; $p < .05$); and present tobacco usage (more noise-susceptible aviators were currently smokers; $p < .05$). The noise susceptible population also tended ($p < .10$) to exhibit elevated cholesterol and triglyceride levels, higher contralateral acoustic reflexes, and had fewer individuals who had never smoked.

Although no classic profile of the noise-susceptible or noise-resistant individual definitively emerged, results suggested that at least one measurement device (MAID test) may serve as an "early warning" of imminent noise-induced damage. Further research, however, is required to test this possibility. In addition, it is recommended that those variables that were statistically significant in differentiating the two subject groups be routinely gathered in a high noise exposure population whose hearing threshold levels can be monitored over a period of years.